SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD A030077

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) New Infrared Laser Concepts		5. TYPE OF REPORT & PERIOD COVERED 75 Dec 01 - 76 May 31 Semiannual Technical Report. 1 Dec 75-31 May 76
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Walter H. Christiansen		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-0316
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aerospace & Energetics Research Program University of Washington Seattle, Washington 98195		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ARPA Order ~~Number~~ 2840 Program Number 5E20
11. CONTROLLING OFFICE NAME AND ADDRESS Procuring Contracting Officer Office of Naval Research Department of the Navy, Arlington, VA 22217		12. REPORT DATE September 15, 1976 15 Sep 76
		13. NUMBER OF PAGES 9 12p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Office of Naval Research Resident Representative University of Washington 3710 Brooklyn Ave. N.E., Unit No. 2 Seattle, Washington 98105		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study of the possibilities of tunable high power gas lasers is being carried out at the University of Washington. These lasers are also characterized by high energy storage density and are suitable for efficient short pulse operation. This class of lasers is based on the use of homonuclear molecules which normally do not have an infrared radiation spectrum, except under special conditions when collisionally induced dipoles introduce both absorption and emission spectra. These lasers exhibit exceptionally broad band characteristics, low gain and high saturation power. → over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

370 200

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

As part of this interest, the possibilities of lasing homonuclear molecules such as H_2 or N_2 directly without the use of permanent dipole additives is being studied. Basically the idea is to produce an inversion in a gas by a high-pressure e-beam-stabilized electric discharge and then induce radiative transitions via collision partners or electric fields. Of the many molecular possibilities, H_2 has been chosen as a likely candidate for such a laser because of its relatively short wavelength transitions (2.8μ) MICROMETERS and easily achieved population inversion. Gain has been predicted over a bandwidth extending from 2.7μ to 10μ using the principle of collisionally induced dipole. The magnitude of the peak gain which occurs at 2.8μ is proportional to pressure squared and for a mixture of 1 part H_2 and 12 parts Xe equals approximately 5%/meter at 50 atmospheres.

The induced dipole laser (collisional or external electric field induced) represented by this study will be a unique laser. The physics of this laser are different in many ways to more conventional lasers and the laser system would show these differences. For example, the estremely wide bandwidth is a consequence of collisional phenomena at high pressures and not apparent in conventional lasers. The work at the Aerospace Research Laboratory builds on the scientific investigation and measurement of induced infrared activity carried out principally at the University of Toronto. (The USSR appears to have some effort in the electric field induced laser as evidenced by the publication of Basov et.al. We have found theoretically that an e-beam stabilized electric discharge can pump a mixture of high pressure Xe-H_2 or D_2 to storage densities on the order of 1 KJ/lit and be inverted so that lasing can occur between the 1 to 0 level of the vibrational states. Lasing is possible without pre-cooling the mixture.

Form Approved, Budget
Bureau No. 22-R02013

Semiannual Technical Report

September 15, 1976

Period Covered: 75 Dec 01 - 76 May 31

ARPA Order Number 2840

Program Number 5E20

Contractor:
Board of Regents
University of Washington
Seattle, WA 98195

Effective Date of Contract:
75 Dec 01

Contract Expiration Date:
76 Nov 30

Contract Number N00014-75-C-0316

Principal Investigator:
Walter H. Christiansen
Phone: (206) 543-6321

Scientific Officer:
Director, Physics Program
Physical Sciences Division
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

Title: "New Infrared Laser Concepts"

Amount of Contract: $100,000.

TECHNICAL PROGRAM

Summary

A study of the possibilities of tunable high power gas lasers is being carried out at the University of Washington. These lasers are also characterized by high energy storage density and are suitable for efficient short pulse operation. This class of lasers is based on the use of homonuclear molecules which normally do not have an infrared radiation spectrum, except under special conditions when collisionally induced dipoles introduce both absorption and emission spectra. These lasers exhibit exceptionally broad band characteristics, low gain and high saturation power.

As part of this interest, the possibilities of lasing homonuclear molecules such as H_2 or N_2 directly without the use of permanent dipole additives is being studied. Basically the idea is to produce an inversion in a gas by a high-pressure e-beam-stabilized electric discharge and then induce radiative transitions via collision partners or electric fields. Of the many molecular possibilities, H_2 has been chosen as a likely candidate for such a laser because of its relatively short wavelength transitions (2.8μ) and easily achieved population inversion. Gain has been predicted over a bandwidth extending from 2.7μ to 10μ using the principle of collisionally induced dipole. The magnitude of the peak gain which occurs at 2.8μ is proportional to pressure squared and for a mixture of 1 part H_2 and 12 parts Xe equals approximately 5%/meter at 50 atmospheres.

The induced dipole laser (collisional or external electric field induced) represented by this study will be a unique laser. The physics of this laser are different in many ways to more conventional lasers and the laser system

would show these differences. For example, the extremely wide bandwidth is a consequence of collisional phenomena at high pressures and not apparent in conventional lasers. The work at the Aerospace Research Laboratory builds on the scientific investigation and measurement of induced infrared activity carried out principally at the University of Toronto.[1,2,3,4] (The USSR appears to have some effort in the electric field induced laser as evidenced by the publication of Basov et.al.[5] We have found theoretically that an e-beam stabilized electric discharge can pump a mixture of high pressure $Xe\text{-}H_2$ or $Xe\text{-}D_2$ to storage densities on the order of 1 KJ/lit and be inverted so that lasing can occur between the 1 to 0 level of the vibrational states. Lasing is possible without pre-cooling the mixture. The preliminary details of this study were published in reference 6.

During 1975, experimental apparatus was constructed to investigate the possibilities of a collisionally-induced dipole laser. The experimental tasks involved in using the apparatus during the report period will be described below.

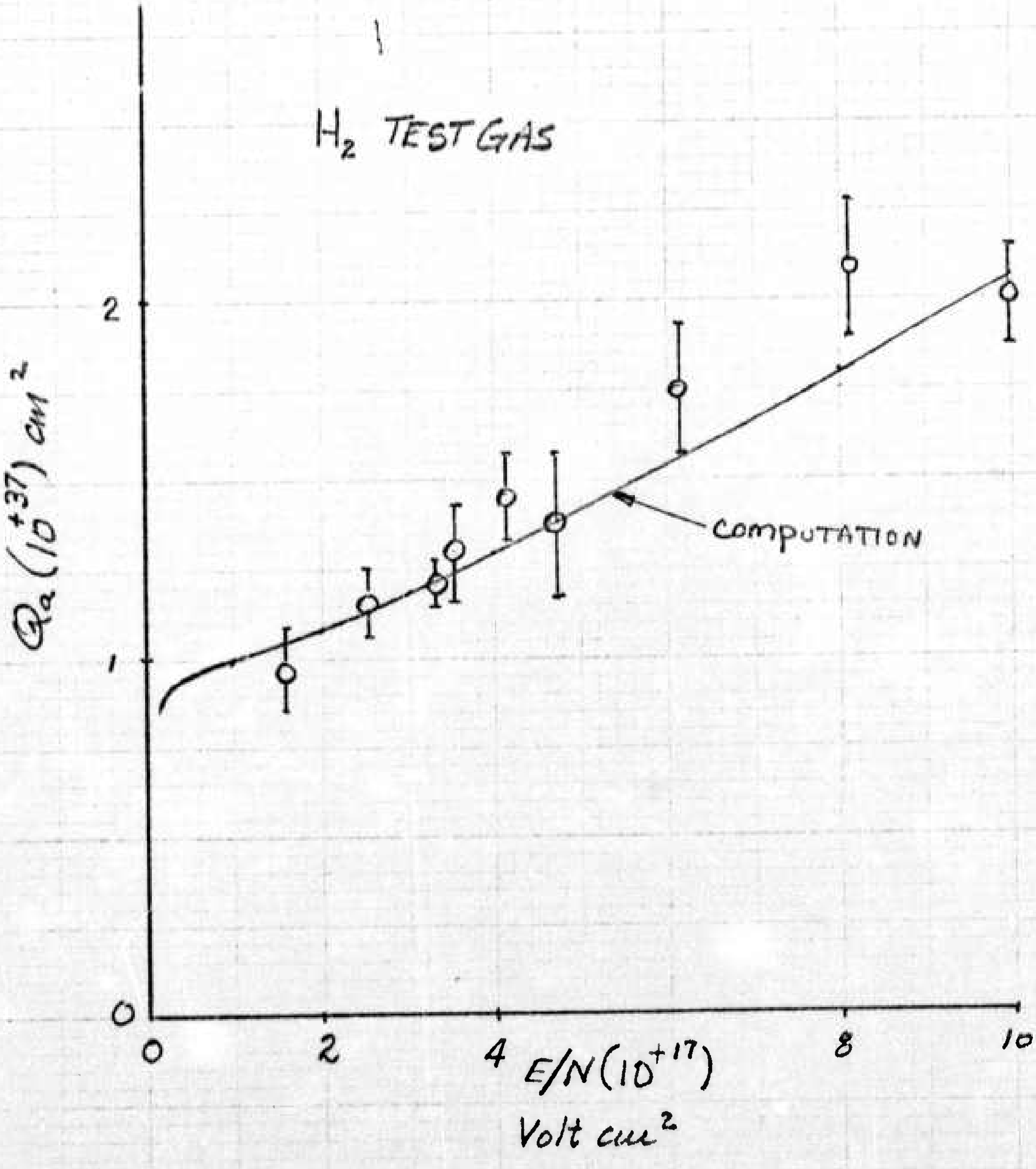
Technical Progress and Tasks

As part of the new infrared laser program the following tasks are being studied during this report period:

1. Electron-Neutral Inverse Bremsstrahlung Measurements: The important effects of inverse bremsstrahlung on gain measurements was mentioned in reference 6. Accordingly a large portion of our research effort is devoted toward quantitatively assessing this phenomena. We are attempting to measure this continuum background absorption at three wave lengths, 0.63μ, 2.8μ, and 10.6μ in order to assess its wavelength dependence. Cursory measurements at 0.63μ indicate no detectable absorption, as might be expected at our electron densities (0 (10^{14})/ cm^3). On the other hand a rather complete survey of the absorption

vs E/N (electric field/no. density) at 10.6μ has been done in N_2 and H_2 gases. A mixture of H_2-Xe was also tried, but a mechanical failure of the e-beam foil window resulted in the mixture being lost. The absorption data @ 10.6μ was analyzed and compared with predictions. Based on our numerical analysis of the Boltzmann equation for secondary electrons in the sustainer, we have computed the absorption cross section to be expected on the basis of the theory of Bekefi[7] and Bunkin et.al.[8] The absorption coefficient is defined as the product NeN Q_a, where Ne is electron density, N neutral density, and Q_a is the absorption cross section. The results of this analysis is shown in fig. 1 for H_2. While there is considerable scatter in the experimental results (vertical bars) there is good overlap wi the predictions for the cross section as E/N. A similar graph exists for N_2. Measurements at 2.8μ are being tried now.

2. V-V Rate Measurement in D_2: No measurements of the VV rates in homonuclear molecule exists to our knowledge. We are attempting a measurement of the VV rates in D_2 via the laser fluorescent technique as part of our program. D_2 is being used instead of H_2 for the measurement because of the need to maximize the laser absorption. But the results will presumably be similar to those of H_2. Measurement of V-V energy transfer rates will be obtained in vibrationally excited D_2 and HD. By absorbing a short pulse of HF laser radiation (≈1 joule in 30 nsec), the D_2 molecules are excited to the first vibrational level. The V-V rates will be obtained by recording the time variation of the collision-induced spontaneous overtone emission radiation from the second vibrational levels. The electrical discharge of the HF laser has been studied and is now operational. A

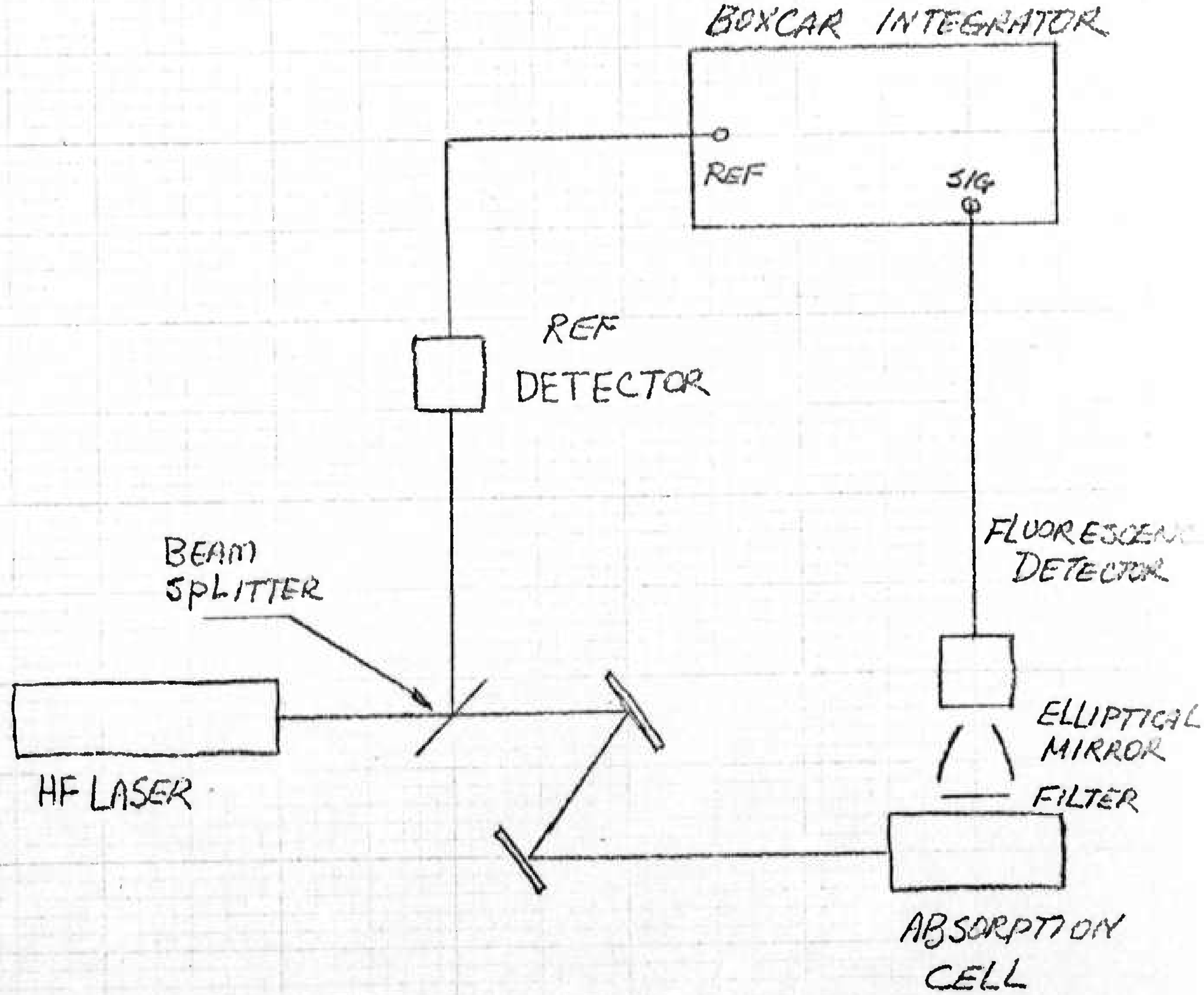


ABSORPTION CROSS SECTION VS E/N

FIGURE 1

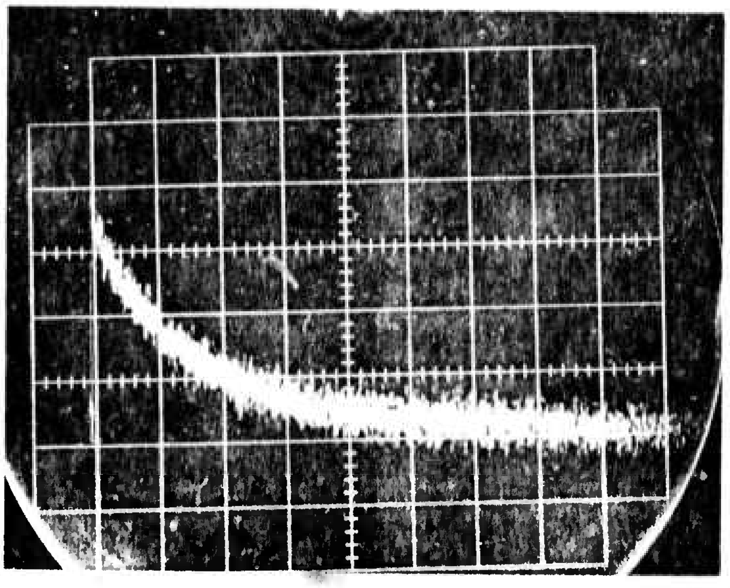
schematic of the experimental apparatus which was previously described is shown in fig. 2.

The main thrust of this project in the past 6 months has been optimizing the detection system and minimizing the scattering light from the HF laser which masks the weak fluorescence from D_2. Electrical noise from the discharge has been almost completely eliminated by using an aluminum Faraday cage which encloses the laser and its power supply. In addition the detector and associated electronics have been shielded. Elimination of scattered laser light which interfers with the fluorescent signal has been difficult to achieve (laser power is a few megawatts, fluorescence power $\simeq$ 10 μW). The combination of 2 multilayer dielectric filters in front of the detector and a C_2H_2 gas cell to absorb the scattered laser light closest to the fluorescence wavelength was insufficient. To eliminate additional reflections inside the pressure cell, a very steep cone was mounted on the back of the cell and painted with optical black as was the entire inner surface of the cell. This reduced the scattered light to a tolerable level, but it was found that the HF pulse vaporized the paint, introducing a foreign gas into the D_2-Xe mixture, creating a fluorescent signal considerably greater than expected for D_2. Presently an aluminum reflector is used in the back of the cell so that most of the light will be focussed back out of the entrance window. It was found that the lens system for collecting the fluorescence was focussing only a few tenths of a percent of the fluorescence onto the detector - an insufficient power to observe the signal. The lens was replaced by an elliptical reflector that increases the collected light on the detector by a factor of 6. Furthermore, a current to voltage amplifier has been employed in the detection system that

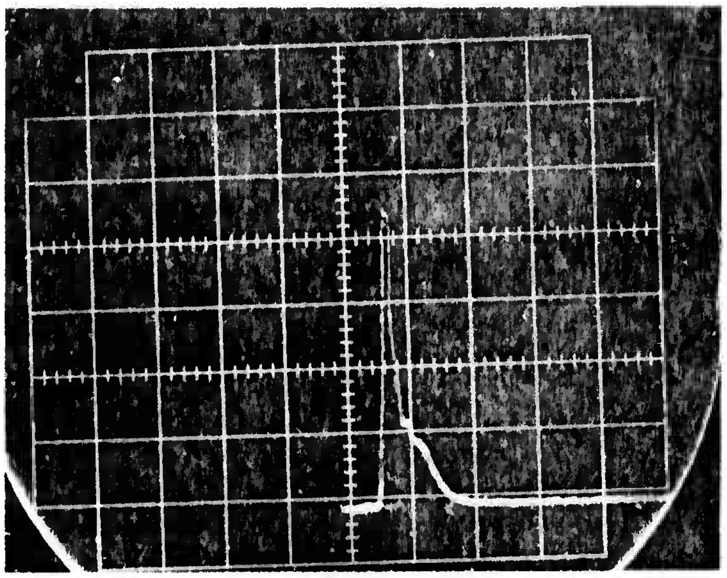


D_2 LASER FLUORESCENCE EXPERIMENT

FIGURE 2



CO_2 FLUORESCENCE SIGNAL
5 μsec/cm



CORRESPONDING HF LASER PUMP SIGNAL
0.1 μsec/cm.

FIGURE 3

has increased the responsivity to the point where the noise observed is dominated by detector noise, while maintaining a time constant RC < 1 μsee - i.e., we have achieved optimum detectivity for our detector.

As a diagnostic for the detection system, the fluorescence of CO_2 at 4.3μ has been observed, following HF laser pumping of the 000 → 021 transition. A typical output of the detected fluorescence is shown in fig. 3. In this figure the horizontal scale is in 5 μsec/cm while the vertical scale is in arbitrary units of fluorescent intensity. The HF laser pulse is short being only 0.2 μsec duration so that the resulting signal is nearly that of a simple experimental decay. As VV exchange between the modes of CO is extremely rapid (order of 2 eollisions), the fluoreseence corresponds to the radiative decay of the 001 level.[9] We have measured the V-T relaxation rate to be $p\tau = 2.5 \pm 0.5$ msec - torr for the 001 level in pure CO_2. We will eontinue these measurements at high pressure and with foreign buffer gases to determine the influence of 3 body eollisions after the fluorescence measurements for D_2 have been accomplished. We have also measured the absorption coefficient of the prineipal absorbing rotational line of the CO_2 and the frequency differenee between the laser signal and absorber for this line.

3. Gain Measurements: No gain measurements on H_2-Xe mixtures have been earried out during this period. It was felt that this measurement should be delayed (until the inverse bremsstrahlung measurements were completed).

References:

1. M.F. Crawford, H.L. Welsh, J.C.F. MacDonald, and J.L. Locke, Phys. Rev. 77, 469 (1950).

2. D.A. Chisholm, and H.L. Welsh, Can. J. of Phys. 32, 291 (1954).

3. Z.J. Kiss, H.P. Gush, and H.L. Welsh, Can. J. of Phys. 37, 362 (1959).

4. Z.J. Kiss and H.L. Welsh, Can. J. Phys. 37 1249 (1959).

5. N.G. Basov, A.N. Oreavski, and A.F. Suchkov, JEPT Lett. 16 212 (1972).

6. W.H. Christiansen and E. Greenfield, Appl. Phys. Lett. 23, 623 (1973).

7. G. Bekefi, "Radiation Processes in Plasmas," Wiley, N.Y. (1966).

8. F.B. Bunkin, A.E. Kazakov, and M.V. Fedorov, Sov. Phys. USPEKHI, 15, 4 (1973).

9. J. Finzi and C.B. Moore, J. Chem. Phys. 63, 2285 (1975).